Optimization of Quantitative and Qualitative yield of different Cauliflower hybrids (*Brassica oleracea* var. botrytis) in Integrated Bio-Organic Fertilization Frameworks under Central Iraq condition

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Abstract

A field experiment was carried out in a private farm which is situated 40 km north of Babylon Governorate in Al-Musaynib district in Al-Azzawiya region in the 2025-2026 agricultural season. The study aimed at exploring the effect of bio-fertilizers (Bacillus sp. and Azotobacter) combined with Vermicompost Organic Fertilizer and its effect on some growth indicators quantitative and qualitative yield traits of three hybrids of cauliflower under environmental conditions of Babylon Governorate. The experiment consisted of two factors: the first factor was the three hybrids of cauliflower with different colors of the head, namely 'Olive Branch' (white curd), ‘Tokato F1' (white curd) and ‘Violetto di Sicilia' (purple curd). The second factor included seven bio-organic fertilization treatments, which were a control (no addition), Bacillus sp., Azotobacter, Daptozoa, Trichoderma, and T. viridescens.The second factor was seven bio-organic fertilization treatments including a control (no addition), Bacillus sp., Azotobacter, Daptozoa, Trichoderma, and T. viridescens. They were applied as: Bacillus sp. + vermicompost organic fertilizer, Azotobacter + vermicompost organic fertilizer, Azotobacter, Bacillus sp. + Azotobacter, and vermicompost organic fertilizer (applied at 10 g plant^{-1}).

The experiment was designed as Randomized Complete Block Design (RCBD) with split plot system and three replications. The main plots were allocated to the cauliflower hybrids whereas the bio-organic fertilization treatments were applied to the sub-plots. The Least Significant Difference (LSD) test was used to compare the means of treatment at p= 0.05.

The data showed that significant differences existed between the hybrids for most of the quantitative and qualitative yield indicators. The 'Olive' hybrid showed a total yield of 27.00 tons ha-1, 16.33 leaves plant-1, leaf phosphorus percentage of 0.511 % and mean plant height of 55.34 cm which was significantly higher than the other hybrids. Moreover, there were appreciable variations in the field of bio-organic fertilization. The total yield of 30.63 tons ha^{-1}, the leaf number of 14.85 leaves plant^{-1}, the curd weight plant^{-1} of 766 g and the highest chlorophyll content of 114.5 SPAD, and leaf potassium percentage of 1.006% were the highest of all treatments when the combined treatment with Bacillus sp. + Azotobacter + vermicompost

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was applied.

There was a significant effect on most growth, quantitative and qualitative yield traits from the binary interaction. Maximum curd weight was recorded in the treatment 'Olive' hybrid with integrated fertilizer treatment (Bacillus sp. + Azotobacter + vermicompost) with 980 g, an average of 39.21 tons ha^{-1} and the maximum chlorophyll content 125 SPAD. This study aimed at evaluating the effects of Cauliflower hybrids, Bio-fertilizers (Bacillus sp., Azotobacter and Vermicompost), quantitative yield and chlorophyll content under Central Iraqi conditions.

Introduction

Cauliflower is part of the Brassicaceae family (Brassica oleracea var. botrytis). It thrives best in temperate or cool conditions and its edible curd is produced on this. Cauliflower has high nutritional value and is rich in essential nutrients, thus contributing to global food security. The edible part of it contains about 92 g of water, 2.4 g of protein, 25 calories, 4.9 g of carbohydrates, 2.2 mg of calcium, 1.1 mg of iron, 72 mg of phosphorus and other vitamins per 100g [1]. The farmers like to grow cauliflower because of its quick turnaround period, ease of cultivation, and high income generation and nutrition. Consumer demand for this has grown significantly as awareness of the nutritional, economic and health benefits have increased. The cultivated land in Iraq amounted to 803 hectares with 8,993 tons of production and 11.19 tons/ha of productivity [2].

Several factors affect the growth of the cauliflower, which are genetic factor (variety and type), environmental factors, agricultural practices, especially nutrient management. Fertilizers are an important component for soil fertility and improving productivity and nutritional quality of crops. But, if nutrients are not replenished regularly, the fertility of the soil decreases, which is a great challenge in ensuring sustainable food production [3]. Use of chemical fertilizers is widespread in intensive farming because of their high nutrient percentage, ease of application and their quick response from the crop. However, their overuse and misuse have resulted in soil degradation, reduced microbial activity, and environmental and health effects [4].

As a result, organic and bio-fertilizers have become more and more popular as alternative sustainable technologies. They help to modify soil physical and chemical characteristics, activate microbial functions and preserve the environment [5]. However, there are some limitations of organic production systems, including the demand for a large amount of land and the higher production costs that can lead to higher consumer prices. Despite these limitations, organic agriculture has a proven track record of expansion worldwide because of increasing awareness of the consequences of using chemical inputs on the environment and on health, which is leading consumers to choose products that are both safer and more sustainable. [6]

Optimal growth, yield and quality depend upon fertilization to achieve best results. The application of fertilizers has a significant effect on productivity. Chemical fertilizers are very productive, but have a great risk in human health because the level of nitrate and oxalate is greatly enhanced and the edible parts are toxic. So, the focus of modern research is minimizing the use of

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mineral fertilizer and applying practices that make nutrient available in soil and to the plants, including bio-fertilization. These microorganisms can live in association with plant and stimulate its growth with the provision of required nutrients. These microbes are very symbiotic, and environmentally friendly, unlike chemical products and more accessible. They form a rich microbial environment, the rhizosphere, which is the thin soil layer surrounding plant roots (0–30 mm), and is a very rich microbial environment. Bio-fertilizers can be applied in the field, close to the developing roots; mixed with seed and/or root-dipped in the seedling stage [7]. At the same time, the use of organic fertilization has positive effects on humans, animals and plants without causing pollution, accelerating of plant growth, improvement of production, enhancement of soil properties, increasing humus content in the soil and improving the absorption of essential nutrients (NPK). So, the best use of organic fertilizers is the key to sustainable development [8]. The present study tried to assess the effect of bio-organic fertilization (in a single or combined dose) along with the genetic differences between the cauliflower hybrids on vegetative growth, chlorophyll content and nutrient accumulation. This improvement is thought to be due to increased nutrient uptake efficiency, cell division and growth, and top growth, which results in a greater overall harvest. This study aimed to:

2. Test the growth and yield characteristics of three hybrids of cauliflower in the environmental condition of Babylon Governorate.

2. Examine the direct effect of bio-organic fertilizers on the growth and yield of these three cauliflower hybrids.Materials and Methods

Seeds of the three cauliflower hybrids were sown in a private nursery using cork trays under optimal growth conditions inside a wire shade house. Seedlings were transplanted into the permanent field upon reaching the stage of 4–5 true leaves on September 26, 2025. Each experimental unit accommodated 12 seedlings distributed across two lines per terrace, maintaining a plant-to-plant distance of 50 cm, with one seedling per hill. The total plant population across the experiment was 756 plants. Re-planting (gap-filling) was performed 7 days post-transplanting. All standard agricultural practices, including weed management, insect control, and irrigation via a drip irrigation system, were strictly executed until the conclusion of the experiment.

Experimental Treatments

This experiment examined two different factors:

First Factor (Cauliflower Hybrids): Three cauliflower hybrids were used, differing in curd coloration:

White-curd hybrid from Italy, 'Olive Branch.

'Tokato F1' is a white-curd Japanese hybrid.

Violetto di Sicilia: Purple-curd hybrid from Italy.

Second factor (Bio-Organic Fertilation): Seven levels of fertilization were used:

Control treatment – no addition.

Bacillus sp. bacteria; (Single dose of 10 g plant-1 on an organic carrier).

3. Azotobacter bacteria (single dose application of 10 g plant^{-1} using organic

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carrier).

4. Vermicompost Organic Fertilizer (6 tons ha-1 which is 150 g plant-1).

5. Bacillus sp. + vermicompost.

6. Azotobacter + vermicompost.

7. Bacillus sp. + Azotobacter + Vermicompost.

Vermicompost was applied at 150 g per plant while the bacterial treatments were applied after transplanting at 10 g per plant.

Experimental Design

It was designed as 3 x 7 factorial experiment using split plot design in Randomized Complete Block Design (RCBD) with three replications. There were three terraces per replication (3 m length x 1 m width) giving an experimental unit area of 3 m^2. The plants were grown in both rows of the terrace with 12 plants per unit spaced 50 cm apart in the row. The distance between neighbouring terraces was kept at 1 m and a buffer zone between replications of 1 m was remained. Bio-organic fertilization treatments constituted the sub-plots and the cauliflower hybrids were the main plots.

Studied Growth Indicators

Vegetative Parameters

Plant height (cm): This was determined for the plants selected in each experimental unit from the ground level surface to the tip of the highest leaf on a plant using a flexible measuring tape and averaged.

The number of leaves was counted in the selected plant during the mature curd stage and the average taken as Number of Leaves (leaves plant^{-1}).

3. Dry Matter Percentage (%): Found by the formula: Dry Matter % = (Plant Sample Dry Weight / Plant Sample Fresh Weight) x 100.

Relative Leaf Chlorophyll Content (R.L.C.C. = SPAD Unit): The values obtained from 6 plants in experimental unit (three readings in each plant) at the proper stage by using a Japanese-made Konica Minolta Chlorophyll Meter and the mean value was expressed as SPAD unit [9].

Quantitative Yield Parameters

1. Curd Weight (g): weight of mature curds from 6 selected plants of experimental unit and mean of the weights.

Total Yield (tons ha^{-1}): Calculated from the yield of the experimental unit, using the density formula Total Yield (tons ha^{-1}) = Yield per Plant (tons) x Plant Density per Hectare (40,000 plants ha^{-1}).

3. Days from Transplanting to 50% Curd Harvest: This was based on the interval of time between the date of transplanting and the day when 50% of the total curds were matured.

Chemical Parameters

The Leaf Nitrogen Percentage (%N) is estimated by using Micro-Kjeldahl apparatus using standard methods [10].

Leaf Phosphorus Percentage (%): Using ammonium molybdate and ammonium vanadate. The intensity of the yellow color was spectrophotometrically measured at a wavelength of 430 nm [11].

3. Leaf Potassium Percentage (%), estimated using a flame photometer, using known

procedures[12].

4. Curd Protein Percentage (%): It is the percentage of protein content in the curd determined initially on dry weight basis by the following equation: Protein % on Dry Basis = Nitrogen % x 6.25 [13]. After this, the protein percentage was calculated on a fresh weight basis as follows: Protein % on Fresh Basis = (Protein % on Dry Basis x Plant Sample Dry Weight) / 100.3. Results and Discussion

There were marked differences between the cauliflower hybrids for plant height as presented in Table 1. The hybrid 'Violetto' produced the maximum mean plant height of 55.34 cm which was significantly higher than both the hybrid 'Olive' and the hybrid 'Tokita' while the hybrid 'Tokita' had a mean plant height of 44.56 cm which was not significantly different from the hybrid 'Olive'. Further, no significant differences existed among the different bio-organic fertilisation treatment on plant height.

There were also considerable differences in regard to the binary interaction. This hybrid 'Violetto' along with integrated treatment (Bacillus + Azotobacter + Vermicompost) produced the maximum plant height of 55.63 cm. Under the other interaction, between the 'Olive' hybrid and the individual Azotobacter treatment, the lowest value (30.57 cm) was obtained.

Table 1: Effect of hybrids, bio-organic fertilization, and their interaction on the mean plant height of cauliflower (cm)

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	31.23	55.53	30.70	39.16
Bacillus	35.90	55.29	30.63	40.61
Azotobacter	30.83	55.35	30.57	38.92
Vermicompost	31.23	55.20	30.73	39.06
Bacillus + Vermi	31.40	55.10	30.73	39.08
Azotobacter + Vermi	33.13	55.27	30.73	39.71
Bacillus + Azoto + Vermi	31.07	55.63	31.20	39.30
Hybrid Average	**32.11**	**55.34**	**30.76**	
L.S.D 0.05	**Hybrids = 12.69 | Interaction = 12.43 | Fertilization = ns**			

There is a wide range of leaf numbers per plant among the hybrids (Table 2). The 'Olive' hybrid had the highest average leaf number of 16.33 leaves per plant and was significantly different from the other two hybrids 'Violetto' and 'Tokita'. The 'Tokato' hybrid had the least average leaf numbers (12.93/plant).

Bio-organic fertilization treatments also had a significant effect and the optimum leaf count of 14.85 leaves plant^{-1} was obtained with the combined treatment of Bacillus, Azotobacter and Vermicompost while the control treatment recorded the lowest mean of 13.31 leaves plant^{-1}. The differences were very high in the case of binary interaction as 'Olive' hybrid with Bacillus + Vermicompost resulted in maximum leaves

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(plant-1) (16.66), while ‘Tokita' hybrid under control condition gave minimum leaves (plant-1) (11.83).

Table 2: Effect of hybrids, bio-organic fertilization, and their interaction on the average leaf number of cauliflower (leaves plant⁻ ¹)

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	11.83	12.44	15.66	13.31
Bacillus	13.05	13.50	16.66	14.40
Azotobacter	12.16	13.05	16.61	14.08
Vermicompost	13.16	13.94	16.55	14.55
Bacillus + Vermi	13.11	14.04	16.66	14.60
Azotobacter + Vermi	13.55	14.00	16.42	14.66
Bacillus + Azoto + Vermi	13.61	15.22	15.72	14.85
Hybrid Average	**12.93**	**13.74**	**16.33**	
L.S.D 0.05	**Hybrids = 1.85 | Interaction = 3.40 | Fertilization = 1.95**			

As shown in Table 3, the hybrid 'Violetto' had the highest average chlorophyll content with a value of 89.5 SPAD followed closely by ‘Olive' 87.5 SPAD with significant variation compared to ‘Tokita' 75.1 SPAD that had the lowest chlorophyll content.
For fertilization, the treatment (fully integrated) Bacillus + Azotobacter + Vermicompost recorded a high chlorophyll value of 114.5 SPAD which was significantly better than the control (48.3 SPAD). The trend of the binary interaction was significantly different, with the highest value of 125.0 SPAD obtained by the hybrid 'Olive' along with the application of Bacillus + Azotobacter + Vermicompost, while the lowest value of 39.49 SPAD was obtained for the same hybrid under control condition.

Table 3: Effect of hybrids, bio-organic fertilization, and their interaction on the relative leaf chlorophyll content of cauliflower (SPAD)

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	58.9	46.5	39.49	48.3
Bacillus	78.3	83.6	97.0	86.3
Azotobacter	62.6	94.8	71.6	76.4
Vermicompost	74.3	109.2	79.5	87.6
Bacillus + Vermi	66.8	84.0	79.6	76.8
Azotobacter + Vermi	76.9	98.0	120.4	98.5
Bacillus + Azoto	108.0	110.6	125.0	114.5

+ Vermi				
Hybrid Average	**75.1**	**89.5**	**87.5**	
L.S.D 0.05	**Hybrids = 12.19 | Interaction = 49.44 | Fertilization = 30.38**			

Table 3 indicates that the average chlorophyll content of the hybrid 'Violetto' (89.5 SPAD) was significantly higher than that of 'Olive' (87.5 SPAD) and the minimum observed value was for 'Tokita' with an average of 75.1 SPAD.
In terms of fertilization, the fully integrated treatment (Bacillus + Azotobacter + Vermicompost) resulted in a significantly higher chlorophyll content, which was 114.5 SPAD, while the control treatment was 48.3 SPAD. Similarly, the trend of the binary interaction was significantly positive with the 'Olive' hybrid and Bacillus + Azotobacter + Vermicompost giving the highest value of 125.0 SPAD while control conditions gave the lowest value of 39.49 SPAD.

Table 4 shows that there are considerable differences in curd weight of the different cauliflower hybrids. The 'Olive' hybrid produced the maximum mean curd weight of 675 g which was better than 'Tokita' and 'Violetto'. In the 'Tokita' hybrid, curd weight was the lowest (366 g) with no significant difference from 'Violetto'.
In regard to the fertilization treatment, the combination of Bacillus + Azotobacter + Vermicompost gave an average result of 766 g curd weight and the control treatment gave the least result of 293 g. The interaction of 'Olive' x Bacillus + Azotobacter + Vermicompost gave highest curd weight of 980 g while 'Tokita' x Control gave the lowest curd weight of 25.0 g.

Table 4: Effect of hybrids, bio-organic fertilization, and their interaction on the mean curd weight of cauliflower (g)

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	250	251	378	293
Bacillus	298	450	709	486
Azotobacter	324	499	640	488
Vermicompost	313	345	470	376
Bacillus + Vermi	394	449	746	530
Azotobacter + Vermi	437	512	802	584
Bacillus + Azoto + Vermi	548	769	980	766
Hybrid Average	**366**	**468**	**675**	
L.S.D 0.05	**Hybrids = 133.9 | Interaction = 175.0 | Fertilization = 88.7**			

From the results presented in Table 5, it is observed that the total yield average of

hybrid 'Olive' was significantly higher than the hybrids 'Violetto' and 'Tokita' with 27.00 tons ha^{-1}, respectively. The 'Tokita' hybrid, on the other hand, showed the smallest average of the total yield, 14.66 tons ha^{-1}.
The total yield was significantly increased in case of bio-organic fertilization, with the highest average of 30.63 tons ha^{-1} in the case of treatment with BC, Azotobacter, and Vermicompost and the lowest yield of 11.72 tons ha^{-1} in control. The results showed that the application of integrated fertilizer treatment (Bacillus + Azotobacter + Vermicompost) gave the highest yield of 39.21 tons ha^{-1} and the lowest yield was obtained with 'Tokita' under control (10.01 tons ha^{-1}).

Table 5: Effect of hybrids, bio-organic fertilization, and their interaction on the total yield of cauliflower (tons ha^{-1})

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	10.01	10.05	15.11	11.72
Bacillus	11.93	18.00	28.35	19.43
Azotobacter	12.95	19.96	25.60	19.50
Vermicompost	12.53	13.78	18.82	15.04
Bacillus + Vermi	15.76	17.98	29.83	21.19
Azotobacter + Vermi	17.48	20.49	32.07	23.35
Bacillus + Azoto + Vermi	21.92	30.77	39.21	30.63
Hybrid Average	**14.66**	**18.72**	**27.00**	
L.S.D 0.05	**Hybrids = 5.35 | Interaction = 7.00 | Fertilization = 3.54**			

Table 6 shows that there are significant differences between the hybrids in the time needed to achieve 50% curd harvest. The 'Olive' hybrid had a considerable advantage in the number of maturity days (137.57 days), trailed by 'Tokita' (143.57 days) and 'Violet' (161.62 days) hybrid.
Fertilization treatments also showed significant effect on hastening the maturity with fully integrated treatment (Bacillus + Azotobacter + Vermicompost) and dual treatment (Bacillus + Vermicompost) requiring 140.33 days of harvests while the control treatment required 155.67 days to mature. The hybrid 'Tokita' x 'Olive' under integrated bio-organic had the shortest duration of 134.00 days compared to a maximum of 170.00 days for the hybrid 'Violet' under control, individual Bacillus and individual Azotobacter treatments.

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Table 6: Effect of hybrids, bio-organic fertilization, and their interaction on the number of days from transplanting to 50% curd harvest

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violet	Hybrids: Olive	Fertilization Average
Control	153.00	170.00	144.00	155.67
Bacillus	153.00	170.00	139.00	154.00
Azotobacter	153.00	170.00	139.00	154.00
Vermicompost	144.00	160.00	139.00	147.67
Bacillus + Vermi	134.00	155.33	134.00	141.11
Azotobacter + Vermi	134.00	153.00	134.00	140.33
Bacillus + Azoto + Vermi	134.00	153.00	134.00	140.33
Hybrid Average	**143.57**	**161.62**	**137.57**	
L.S.D 0.05	**Hybrids = 0.75 | Interaction = 1.45 | Fertilization = 0.84**			

The leaf N percentage for each of the cauliflower hybrids was not significantly different as shown in Table 7. But this fertilization treatments resulted in significant rise as minimum value was 1.87% in control and highest value was 2.99% in fertilization by Azotobacter. Factors interactions was also significant with the highest nitrogen percentage of 3.38% observed for the 'Olive' hybrid in the presence of Azotobacter + Vermicompost and the lowest number of 1.63 for the 'Violetto' hybrid when grown under control condition.

Table 7: Effect of hybrids, bio-organic fertilization, and their interaction on the leaf nitrogen percentage (%) of cauliflower

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	1.89	1.63	2.10	1.87
Bacillus	3.50	2.52	2.15	2.72
Azotobacter	3.27	3.31	2.40	2.99
Vermicompost	3.08	2.61	2.19	2.63
Bacillus + Vermi	2.45	3.66	1.98	2.70
Azotobacter + Vermi	2.33	2.89	3.38	2.87
Bacillus + Azoto + Vermi	2.26	2.03	2.15	2.14
Hybrid Average	**2.68**	**2.67**	**2.34**	
L.S.D 0.05	**Hybrids = n.s | Interaction = 1.77 | Fertilization = 0.95**			

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Among the hybrids, significant differences in leaf phosphorus content are shown in Table 8. The highest percentage of phosphorus (0.511%) was obtained by the 'Olive' hybrid, which was significantly higher than the 'Violetto' and 'Tokita' hybrids, and the lowest percentage was obtained by the 'Tokita' hybrid (0.436%).

The individual application of Bacillus was the fertilization level that had the highest concentration of phosphorus (0.574%), greater than the individual application of the control fertilization (0.339%). In addition, the interaction was important and the hybrid 'Olive' combined with individual Bacillus showed the highest phosphorus concentration (0.790%), while the hybrid 'Tokita' in control condition the phosphorus concentration was the lowest (0.280%).

Table 8: Effect of hybrids, bio-organic fertilization, and their interaction on the leaf phosphorus percentage (%) of cauliflower

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto di Si	Hybrids: Olive	Fertilization Average
Control	0.280	0.348	0.390	0.339
Bacillus	0.383	0.549	0.790	0.574
Azotobacter	0.472	0.561	0.444	0.492
Vermicompost	0.704	0.388	0.439	0.510
Bacillus + Vermi	0.448	0.500	0.607	0.518
Azotobacter + Vermi	0.318	0.416	0.537	0.424
Bacillus + Azoto + Vermi	0.446	0.306	0.374	0.375
Hybrid Average	**0.436**	**0.438**	**0.511**	
L.S.D 0.05	**Hybrids = 0.096 | Interaction = 0.266 | Fertilization = 0.160**			

According to Table 9, cauliflower hybrids did not manifest significant differences regarding leaf potassium accumulation. However, bio-organic treatments induced highly significant variations. The fully integrated fertilization treatment (Bacillus + Azotobacter + Vermicompost) produced the highest potassium percentage of 1.006%, which was significantly higher than the control treatment value of 0.558%.

The binary interaction also confirmed significant variations, with the 'Olive' hybrid under the integrated treatment (Bacillus + Azotobacter + Vermicompost) reaching the absolute highest leaf potassium level of 1.528%. Conversely, the 'Tokita' hybrid under control conditions exhibited the lowest potassium level of 0.463%.

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Table 8 shows that there are significant differences in leaf phosphorus content among hybrids. The highest Phosphorus percentage (0.511%) was obtained with the ‘Olive' hybrid, which value is considerably greater than that obtained with the other ‘Violetto' and ‘Tokita' hybrids, which were 0.500% and 0.436%, respectively.

In terms of fertilization levels, the application of Bacillus gave the highest phosphorus concentration (0.574%), statistically significantly higher than the control (0.339%). Moreover, the interaction was significant and the hybrid 'Olive' which received individual Bacillus inoculation had the highest level of phosphorus accumulation (0.790%), while the hybrid 'Tokita' under control conditions had the lowest level (0.280%).

Table 9 shows that, in terms of leaf potassium accumulation, cauliflower hybrids did not show significant differences. The highly significant differences were however brought about by bio-organic treatments. The highest potassium percentage of 1.006% was obtained from fully integrated fertilization (Bacillus + Azotobacter + Vermicompost) which was significantly higher than the control treatment value of 0.558%.

Similarly, the difference between the hybrids was significant under the influence of the binary interaction as well, with the 'Olive' hybrid getting the highest level of potassium in leaves (1.528%) under integrated treatment (Bacillus + Azotobacter + Vermicompost). On the other hand, the 'Tokita' hybrid under control conditions had the lowest potassium level recorded as 0.463%.

Table 9: Effect of hybrids, bio-organic fertilization, and their interaction on the leaf potassium percentage (%) of cauliflower

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	0.463	0.642	0.568	0.558
Bacillus	0.653	0.817	1.078	0.849
Azotobacter	0.580	1.082	0.565	0.742
Vermicompost	0.990	1.147	0.750	0.962
Bacillus + Vermi	0.772	1.117	0.897	0.928
Azotobacter + Vermi	0.886	0.693	0.965	0.848
Bacillus + Azoto + Vermi	0.758	0.742	1.528	1.006
Hybrid Average	**0.729**	**0.891**	**0.907**	
L.S.D 0.05	**Hybrids = n.s | Interaction = 0.570 | Fertilization = 0.283**			

The statistical data in Table 10 disclose no significant differences among the hybrids regarding curd protein content. Nonetheless, bio-organic fertilization significantly impacted protein percentages, where the separate inoculation of Bacillus resulted in the highest average protein percentage of 28.92%, which was statistically higher than

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the control average of 17.64%.
Furthermore, the binary interaction significantly altered protein percentages. The combination of the 'Olive' hybrid with the independent vermicompost treatment recorded the absolute highest protein concentration of 33.40%, whereas the 'Violetto' hybrid under control conditions recorded the minimum value of 14.29%

Table 10: Effect of hybrids, bio-organic fertilization, and their interaction on the curd protein percentage (%) of cauliflower

Bio-Organic Fertilization	Hybrids: Tokita	Hybrids: Violetto	Hybrids: Olive	Fertilization Average
Control	19.98	14.29	18.67	17.64
Bacillus	24.06	33.54	29.17	28.92
Azotobacter	23.77	25.23	22.75	23.92
Vermicompost	21.44	19.69	33.40	24.84
Bacillus + Vermi	24.50	20.85	28.29	24.54
Azotobacter + Vermi	25.67	32.96	25.08	25.76
Bacillus + Azoto + Vermi	21.58	21.15	29.90	24.21
Hybrid Average	**23.00**	**23.96**	**26.75**	
L.S.D 0.05	**Hybrids = n.s | Interaction = 11.28 | Fertilization = 6.69**			

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